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A REVIEW OF DIFFERENT DRYING TECHNIQUES OF FRESHLY HARVESTED MAIZE COBS

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ABSTRACT

At the time of harvesting, maize contains moisture of about 20 – 25% and, in this moisture level, the growth of mould & fungi increases which can cause damage to the grains. The moisture content of 11.8-13%, which is suitable for safe storage, must be achieved after the drying of maize. The passive solar dryer dries grain faster than the open conventional system. It took 2 days for the maize cobs to dry with a stabilized weight of moisture from 30.3 g to 24.3 g using the constructed passive solar dryer, whereas, it took 6 days to dry the same cobs to 25.4 g under the open conventional sun drying system. Maize cobs in the solar dryer looked cleaner compared with the sun drying. The drying of maize to safe moisture content of 14% for 5 days and 6h respectively when taken for drying on bare ground and by the biomass heated natural convection dryer, it reduced the drying time and greatly improved the quality of the grain during storage. The passive universal dryer reduced the moisture content of fresh maize up to the safe storage level 12% (wb) in 12 h resulting in 98% viability of dried maize. Passive universal dried product was more acceptable, neat and spores less food materials, as compared with the sun dried products. The main aim of this research was to review the various types of dryers and drying methods used in drying of maize cobs.

KEYWORDS: ***Maize Cobs, Moisture Content, Dryers, Drying Methods & Temperature***

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INTRODUCTION

Maize (Zea*mays* L.), also known as corn is a large grain plant first domesticated by indigenous people in southern Mexico. Maize is of high importance among the world's cereal crops. Maize can be used for human consumption, animal feed and industrial purposes. Maize is an important cereal crop next to rice, wheat and jowar, in respect of area and production in India. As kharif crop, 85 % of the cultivated area of maize is grown in India, throughout the year in the season. 2.5 per cent of world's maize production is contributed by India and in India; the main states which contribute to the production and area are Rajasthan, Andhra Pradesh, Karnataka, Maharashtra and Uttar Pradesh, together with 70 per cent of maize production and 60 percent of the area under cultivation. The world maize production is estimated about 968 MT in 2015-16 of the International Grain Council report of September 2015, besides the total coarse grain production of 1274 MT in 2015-16. The area under maize production in kharif season was 33.3 Mha; production was 43.4 MT and the yield was 1303 kg/ha. The area under maize in Rabi season was 12.8 Mha; production was 25.8 MT and yield was 2016 kg/ha in Gujarat in 2013-14. The area under maize in kharif season was 772.61 Mha; production was 1767.7 MT and yield was 2288 kg/ha,

and, the area under maize in Rabi season was 169.98 Mha; production was 667.1 MT and the yield was 3925 kg/ha in the year 2013-14 of India. Total area was 942.58 Mha; total production was 2434.75 MT and total yield was 2583 kg/ha in India in 2013-14 (Anonymous, 2014-15). The area under maize was 42.3 Mha; production was 67.2 MT and yield was 1589 kg/ha in Gujarat in 2014-15. In the Panchmahal district, the area was 0.15 Mha; production was 1.17 MT and yield was 927 kg/ha for varieties of GM-4, GM-6, Narmada Moti (Anonymous, 2015). Globally, it is estimated that 84% of produced grains are wasted. In India, 20-40% of food grains are spoiled, due to conventional preservation technique. The preservation techniques like canning, freezing, drying etc. are used in order to avoid the food wastage. The renewable hybrid drying system may be optimum for food preservations at low cost and will exploit in the present scenario. Many traditional and industrial maize processing methods exist. Industrial processing includes wet and dry milling to produce a wide variety of products. Many maize dishes are prepared in Africa and elsewhere, as human food. Maize is one of the staple foods of poor families. Traditionally, the grain is converted into flour in mills for making bread. Immature cobs are roasted and eaten all over the country. The dry starch has a moisture content of 11-12 per cent. Starch, gluten, germ and husk of 60-62%, 8-9 %, 6-7% and 22-24% is the average recovery during wet milling of maize. Nutritional Value of corn is normal as any other cereals. Its grain contains 11.2 % protein, 66.2 % carbohydrate, 3.6 % fat, 1.5 % minerals and 2.7 % fiber (Gopalan*et al.* 1981). Additionally, it contains 90 mg carotene, 1.18 mg, niacin, 0.8 nig thiamine and 0.1 mg riboflavin per 100 g grains. Maize is fairly rich in vitamin B and the yellow kernel is also a good source of the pro-vitamin A, B carotene, which can prevent human blindness.

METHODS OF MAIZE DRYING

In order to increase the shelf life of perishable foods, drying and dehydration play important role. Drying of materials having high moisture content is a complicated process, involving simultaneous heat and mass transfer (Yilbas *et al.* 2003).

- Sun/ Solar drying
- Mechanical drying

REVIEW OF LITERATURE

Mumba (1995) developed a solar grain dryer based on forced circulation, which is powered by the photovoltaic system that is generally used in the tropics. For drying of maize from the developed dryer, from 33.3 % to 20 % moisture content having a capacity of 90kg, it takes one day. **Eke *et al.* (2000)** studied a prototype, direct mode natural convection mud type solar dryer. Based on the workability, availability and thermal properties, the major dryer material was selected as mud by the end users. The testing in laboratory of mud type solar dryers in three large scales was done for a capacity of 400 kg from the initial moisture content of 29% to 12%. 150 kg of maize grain available from the farmers, at 30 % initial moisture content wet basis was dried as a batch in three replicates, to 12 % moisture content wet basis with the dryers. **Santos *et al.* (2005)** developed an in-bin corn drying system that was connected to an energy storage solar collector system (1.8 $m^2$of collector area). The bin volume was 1.77 m^3 and able to load with 1.3 tons of corn (bulk density 721 kg/m^3). Pebble bed was used as the energy storage system. Airflow used for drying was supplied at a rate of 2.1 m^3/min. A saving of 30% in fuel consumption can be achieved by drying under these specifications, at the corn loading of 1.28 tons at 50°C with air flow rate of 1526.8 m^3/day. **Kolling*et al.* (2006)** tested the behavior of fixed bed corn dryer during the operation of drying, on the basis of commercial scale. In these process, different variables i.e. product temperature, airflow, fuel

consumption (corn cobs) and ambient and drying air conditions were controlled. They found that the average drying air temperature was 41.7°C, and also maximum drying air temperature was found to be 42°C inside the dryer. For commercial drying, the drying time over 100 hours is very high. When the moisture content is above 18 %, the 85% of the total time for exhaustive drying was effectively consumed. In the effective drying, the fuel consumption varied from 295 to 365 kg of maize cobs per point removal of moisture, which indicates the consumption more than 16000kJ/kg. It was concluded that drying time in the tested dryer was reduced by 65 hours. **Irtwange and Adebayo (2009)** developed and evaluated a natural convection laboratory-scale passive solar grain dryer of essentially solar collector, drying chamber, heat storage unit, air vents and dryer, which stands with a solar collector absorber plate made of corrugated thick zinc roofing sheet. The solar collector top was made of one layer of 4 mm thickness of colorless glass sheet as glazing and corrugated 0.5 mm painted black thick zinc roofing. The storage unit contains black painted rock pebbles of volume 0.15 m^3 for better heat absorption. The evaluation of the dryer was carried out with 10kg of maize, which is freshly harvested at 32.8% deb. After evaluation it was concluded that the mean rate of sun drying was 0.3125 kg/day, per every 10kg, in comparison with the mean rate of drying which was 0.7kg/day. The solar grain dryer was more time efficient than traditional sun drying. The passive solar dryer took 4 days for drying the maize corn to the final moisture content of 13.1% wb, while the sun drying process took 4 days to the final moisture content of maize of 13.4% wb. **Bhuiyan*et al.* (2010)** studied on the drying of maize cobs which was harvested at the moisture content of 23%, which is relatively higher. The cobs, after dividing in four categories, dried for 24 h at the temperature of 80, 90 or 100°C in the sun or in force draft oven. It was found that in the 100°C samples, the dry matter of 980 g/kg and ash content of 1.32g/kg was the highest, but in the sample, after sun drying had the highest amount of phytate-P (1.8 g/kg), ether extract (45.0 g/kg) and crude protein (98.4 g/kg). The model correctly describes the evolution of moisture content during fluidized- bed drying with constant drying air temperatures between 50 °C and 100 °C. **Kaaya *et al* (2010)** studied drying of grains of maize with the help of two methods, first is drying on the bare ground and second is by the help of biomass dryer. The biomass dryer is more effective than the bare ground drying, as bare ground drying took 5 days to dry the maize to 14% moisture content, but biomass dryer took only 6 h for drying up to same moisture level. There was no effect on the germination of maize from the drying of maize in the biomass dryer. **Abdullah *et al.* (2011)** studied a simple solar drying system that consists of three parts, namely the collector, drying chamber and air blower and investigated for drying maize cobs. The solar collector had a V-corrugated absorption plate of two air passes and covered with single glass. Total collector area measured at 2.04 m^2. The dimension of the drying chamber measured 1.06 m x 0.66 m x 0.56 m, and can be loaded with 38 kg of corn. A moisture content reduction from 21% to 13% can be achieved in 4 hours. The range of drying air temperature obtained was from 30°C to 45°C at ambient condition of 8.5°C to 20°C. The solar collector efficiency can be raised by 3.25% and 11.11% by increasing the volumetric air flow rate from 0.025 m^3/s to 0.03 m^3/s and 0.03 m^3/s to 0.035 m^3/s, respectively. **Kocsis*et al.* (2011)** carried out corn drying experiments with different settings of the pilot dryer to investigate the impact of drying parameters during drying. The drying process depends on several factors, such as drying temperature, air speed, and additional drying conditions. With different settings of the dryer, 3 corn drying series were carried out. In all cases, 80°C, 110°C and 130°C drying temperature and v=0, 129 m/s, Q=115m^3/s; v=0, 225 m/s, Q=200m^3/h and v=0. 409 m/s, Q=360m^3/h; dry air velocity (v) and the volume of the drying air (Q) were combined. The measurement results show that by increasing the temperature or the velocity of the drying air, it was possible to reduce the drying time significantly. From the energy analysis of the measurement series, it appeared that increasing the temperature requires 28.7% higher amount of energy, but the increased velocity of the drying air reduces the energy consumption by 18.9%. **Li *et al.* (2011)** investigated solar assisted heat pump in-store drying of corn. This solar drying system consists of a set of solar collectors, a heat pump and a mechanical grain stirrer. The heat was

generated from the joint solar collector and heat pump system. The purpose of installing the heat pump was to solve the problem of the intermittent availability of solar radiation. Four working modes can be selected depending on the weather conditions, namely the solar energy heating mode, the heat pump heating mode, the solar assisted heat pump heating mode and the heat pump de-humidification mode. An air duct connected the solar assisted hat pump system to the bottom part of the granary. During trials, it was observed that average temperature difference ambient air and granary inlet air were about 8.9°C, while average relative humidity varied from 13.6% to 37.7%, lower than the ambient air. It took about 240 hours to reduce the moisture content of the corn from 16.6% to 14.5% (w.b). Power consumption per grain ton to reduce the moisture content by 1 % was 1.24 kwh, and the value was much lower than the official standard (2.0 kwh). **Ajala *et al.* (2012)** studied on drying kinetics of fermented corn grains. The fermentation of corn grains for the period of three days were occurring and then after, draining were dried in the convective heat dryer at different temperatures of 600, 650 and 700°C. With the help of Fick's second law, the drying kinetics was investigated. In falling rate period, the pattern does drying was observed. To fit the experimental data, the Nonlinear regression analysis software (SPSS) was used, and, for all the models, except Midilli, coefficient of determination was greater than 0.90. The higher rate of 2.0g/HR drying rate data generated was used to design and fabricate the corn-on-cob dryer. **Bola *et al.* (2013)** designed and developed a batch in-bin maize grain dryer. Some properties of maize, such as moisture content and bulk density and other properties of dryer, which is drying chamber dimension, amount of removal of moisture, quantity of air, volume of air, capacity of blower, heat quantity and actual heat required to effect drying were determined to get the information required for the design of the dryer. For threshed wet maize, 100 kg batch size maize dryer was fabricated. For measurement of rate of drying at the different initial temperature of air drying, drying air velocities and grain bids were measured. The locally fabricated dryer was affordable with a total cost of sixty thousand Naira (N 60,000 = 375 USD). **Sahdev *et al.* (2013)** studied on convective heat transfer coefficient for indoor forced convection drying of corn kernels. The drying of maize kernels was made from the 43% dry basis moisture content. By using the analysis by an equation of regression, the data were evaluated to find the values of C a n (constants) in the expression of nusselt number, and consequently, the coefficient of heat transfer was also determined. The coefficient of convective heat transfer of 1.04 W/m^2 °C was found in maize kernels. **Tiwari *et al.* (2013)** studied the different popular solar dryer performance for plain region of India and also done a comparison. They concluded that the solar tunnel dryer and solar hybrid dryer were more suitable because of higher efficiency, commercial viability, high load capacity, higher drying rate and quality of dried product. By using solar hybrid dryer drying time could be reduced and the major advantage of both dryers was that it could be used for multi crops. **Bandara *et al.* (2014)** developed a suitable dryer for drying maize cobs, which would preserve its quality and substantially increases farmers' income. From the developed dryer, the drying of 1000 kg maize cobs from the moisture content of 33.7% (w.b.) to 13% wb within the time interval of 15.5-26.6 hours could be possible at the relevant drying cost of Rs. 1.9-2.68. The average drying air temperature was 46°C. Firewood was used as the fuel and the requirement of firewood was 12kg/HR. **Iqbal and Ahmed (2014)** conducted the experiments to study the drying of the ear-corn as a large chance to improve the method in terms of preserving quality, decreasing cost, and increasing capacity. The objectives of the study were to evaluate selected ear-corn drying techniques, namely sun drying, solar passive ear-corn drying, and heated-air ear-corn drying, to perform the cost analysis of these three techniques, and analyze the comparative performance of these techniques based on field data. They constructed a passive solar dryer to dry ear-corn; the test results indicated that the dryer was found capable to dry 0.5 tons of ear-come from 26.1 to 18.9% moisture content in June, in four days, and from 26.4% to 20.1% in October, two days. **Tonui*et al.* (2014**) designed and evaluated performance of the solar grain dryer with a Back-up Heater**.** The dryer was composed of solar collector, drying chamber, back-up heater and air flow system. The ambience conditions which were

taken during the experiment were relative humidity of 72 % and the temperature of 26°C within the influence of 21.6 MJ/m^2/day global daily solar radiation incidents on the horizontal surface. For the capacity of 100kg maize grain, the required area of collector was 3.77m^2 from the moisture content of 21% to 13% on a wet basis, at the time of 6h, with the drying process of natural convection. The fabrication of designing prototype dryer was done, having the minimum area of collector at 0.6m^2. In order to reduce the time, the employment of forced convection was done. Higher thermal efficiencies were shown by solar assisted dryer of 57.7%, over the solar dryer of 39.9% thermal efficiency. There was improvement in the efficiency by 17.8% and also, the reduction in time was shown by the backup heating system. **Osondu *et al.* (2015)** evaluated the performance of the solar maize dryer. The oldest techniques for drying of food products for the preservation of mankind were drying under direct sunlight.

CONCLUSIONS

The highest product temperature during drying process was 42.0°C and the average temperature was 41.7 °C in fixed-bed ear corn seed dryer, and the drying time could be reduced to 65 hours. The passive solar dryer dries growing faster than the open conventional system, i.e. sunlight. It took 2 days for the maize cobs to dry with a stabilized weight of moisture from 30.3 g to 24.3 g, using the constructed passive solar dryer, while it took 6 days to dry the same cobs to 25.4 g, under the open conventional sun drying system. Maize cobs in the solar dryer looked cleaner, when compared with the sun drying. The drying of maize to safe moisture content of 14%, 5 days and 6h respectively, taken for drying on bare ground and by the biomass heated natural convection dryer reduces drying time, and greatly improves the quality of the grain during storage. Batch type maize dryer, dries 1000 kg of maize cobs containing moisture 26 - 33.7% (w. b.) With final moisture content of 13% within 15.5-26.6 hour, the cost of drying per kg of maize was Rs. 1.9-2.68, and the average drying air temperature was 46 °C when fire wood was used as the fuel. The passive universal dryer drier reduced the moisture content of fresh maize up to the safe storage level 12% (w.b.) within 12 h, resulting in 98% viability of dried maize. From the review of research papers, it has been concluded that, the solar dryers are more beneficial than the traditional sun drying techniques. Solar dryers do have shortcomings. They cannot be used during cloudy weather. During fair weather, they can work too well, but the initial investment is more in these dryers. The product obtained is of good sensory attributes and nutritional quality, increasing the market value and marketability of the product. Solar dryers can perform faster & safe drying and also, they are more efficient than traditional sun drying method. The dried product of passive universal dryer were more acceptable, neat and spores-less food materials in comparison to the sun dried products.

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